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RESEARCH DEPARTMENT

VISIT TO ZÜRICH, DECEMBER 1960

Report No. A-061

(1961/4)

THE BRITISH BROADCASTING CORPORATION
ENGINEERING DIVISION

RESEARCH DEPARTMENT

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1. INTRODUCTION

An invitation was extended by Mr. R.F. Holtz, Managing Director of the Zürich Laboratories of the Radio Corporation of America, for representatives of the B.B.C. Engineering Division to attend a discussion and demonstration on the subject of stereophonic broadcasting systems. The outline agenda sent with the invitation is given in the Appendix. The programme was principally intended for R.C.A. licensees in Europe, to keep them informed about the systems under consideration in the U.S.A. It covered the circuit techniques, particularly in receiver design, that would be required for stereophonic broadcasting using systems which the R.C.A. considered the most promising for the v.h.f. and medium-frequency sound broadcast bands, respectively.

Arrangements were made for the two authors to visit Zürich to attend the so-called "individual conference" on stereophonic systems, on 19th December 1960. No other visitors attended on the same day, the idea being that visitors from various organisations should attend on different days.

2. ZÜRICH LABORATORIES OF THE R.C.A.

The Zürich establishment of the R.C.A. is confined, rather surprisingly, to the third floor of an unpretentious office block, yet a wide range of activities is undertaken. There appeared to be three main groups: first the Industry Service Laboratory, which does work of assistance to manufacturers who are R.C.A. licensees, second the laboratory working on problems connected with actual R.C.A. equipment exported through R.C.A.-International to the European area, and finally the R.C.A. Zürich Research Laboratory, which undertakes fundamental investigations on materials (work on the electrical and optical properties of semiconductors for example) in close co-operation with the R.C.A. Princeton Laboratories in New Jersey, U.S.A.

Our hosts during the visit were Mr. C. Ruth, Manager of the Industry Service Laboratory, and Mr. R.A. Mills. A brief summary of items of interest seen during a quick tour of the establishment, but not connected with stereophony, is given in Section 7. The other sections concern the results of discussions on stereophonic broadcasting, the main purpose of our visit.

3. GENERAL REQUIREMENTS FOR STEREOPHONY

In course of a discussion on the general standards for domestic stereophony, reference was made to recent work in the United States laboratories of both R.C.A. and Bell Telephone Laboratories. Subjective investigations by R.C.A. (as yet unpublished)

on the permissible crosstalk between the left (A) and right (B) stereophonic channels had given a figure of −20 dB for programme material restricted to the band 100 c/s to 10 kc/s, and −15 dB for the full range 30 c/s to 15 kc/s. In answer to a question whether the 15 dB in the latter case applied to the 100 c/s to 10 kc/s region within the main band, it was pointed out that in practice the crosstalk in the middle of the band would be much less than that at the extremes. It is thus reasonable to assume that the experiments indicate that −20 dB or better is desirable in the 100 c/s to 10 kc/s range (otherwise material restricted for some reason to this frequency range at the source would suffer) and that the crosstalk may deteriorate to −15 dB towards the 30 c/s and 15 kc/s limits of the audio frequency range. The work of Bell Telephone Laboratories was not discussed in detail, but we gained the impression that they had come to similar conclusions to R.C.A. regarding permissible crosstalk.

Further unpublished information on a related subject was obtained from an R.C.A. report, which had just arrived in Zürich, giving the observed spread of a stereophonic image as a result of progressive attenuation of the A–B difference signal by 6 dB per octave at high frequencies. Phase compensation had been applied in some of the tests and from the curves produced it was apparent that this refinement allowed the cut-off frequency (arbitrarily defined) of the A–B chain to be lowered by about one octave for the same degree of spreading.

4. STEREOPHONIC SYSTEMS FOR V.H.F. BROADCASTING

4.1. Preferred Systems

For introducing the discussion on the various proposals for stereophonic broadcasting systems a chart had been prepared summarising the main features of the systems examined in the U.S.A. by the National Stereophonic Radio Committee. Besides the American proposals, entries in the table included the E.M.I. coded system and the Mullard system, the latter being referred to as the P.A.M. (Pulse–Amplitude–Modulation) system in the chart; no other European systems were included, presumably since the British systems were the only ones submitted to the N.S.R.C. from outside the U.S.A. The table included theoretical figures for the degradation of signal-to-noise ratio which agreed closely with our own figures in the cases we had calculated (Crosby f.m. sub-carrier system and Mullard system).

We were told that, for conditions in the U.S.A., the R.C.A. preferred a f.m. sub-carrier system, with the main carrier modulated by the M = A+B signal and the sub-carrier modulated by the S = A–B signal. In order to leave space in the modulation spectrum for one or two additional sub-carriers for "Subsidiary Communications Authorization" (S.C.A.) services — i.e. background music, "store-casting", etc., to private subscribers — the R.C.A. prefers a relatively high sub-carrier frequency for stereophony as shown in the first entry of Table 1.

However, for the purpose of the demonstration, a system much closer to the original Crosby proposal had been set up, the parameters being given in the second entry of Table 1. This would be representative of a f.m. sub-carrier system that might be used in Europe, where additional sub-carrier services are of little interest.

TABLE 1

Parameters of f.m. sub-carrier systems

System	Deviation of main carrier (% of ± 75 kc/s)		Sub-carrier frequency (kc/s)	Deviation of sub-carrier by S = A-B (kc/s)	Theoretical degradation of signal-to-noise ratio below standard f.m. (dB)		
	by M = A+B	by sub-carrier			Main channel	S channel	A and B channels
1. R.C.A.-U.S. recommendation	50%	30%	65·5	± 9·5	-6	-30·5	-27·5
2. R.C.A.-Zürich demonstration	50%	50%	58	± 17	-6	-19·7	-16·7

The information in Table 1, including the figures for noise degradation, corresponds to that given to us in Zürich. The degradation would be slightly less severe in stereophonic reception in the case of the first system if allowance were made for the fact that the S signal in this proposal is restricted to a maximum a.f. of 9·5 kc/s, assuming that the full 15 kc/s bandwidth is used for standard f.m. and the M signal.

4.2. Arrangements for Demonstrations

For the purposes of demonstration the "transmitting end" consisted of a matrix unit to produce the M and S signals, a sub-carrier modulator consisting of standard R.C.A. equipment for "store-casting" which had been arranged to operate with a 58 kc/s sub-carrier frequency, and a Boonton f.m. signal generator to which the M and modulated sub-carrier signals were supplied via a combining amplifier. This equipment was in an adjacent office and the r.f. signal was fed to a dipole; a carrier frequency in the 100 to 108 Mc/s range was used.

The "receiving end" consisted of a commercial tuner (Bogen f.m. tuner) with two alternative sub-carrier demodulator and matrixing units. These in turn could be arranged to feed two 15W transistor amplifiers to which a pair of wide-range loudspeakers was connected. A separate self-contained f.m. stereophonic receiver of simple design, feeding two smaller loudspeaker units with a restricted frequency range, was also available. In all cases a simple wire dipole was used as an aerial. The receivers and loudspeakers were set up in Mr. Ruth's office, the acoustics of which were somewhat more live than those of an average living room, and the programme source consisted of a number of stereophonic disks which gave the impression of having been recorded with widely spaced microphones. Making allowance for these limitations, there was no obvious technical deficiency in the stereophonic presentation.

The circuits employed for the stereophonic equipment were described to us in some detail; the principal features of interest are summarised below.

(i) *Transmitter Unit*

The formation of the sum and difference signals was done by means of resistance-capacitance circuits and valves rather than by transformers. The sum signal was fed through a delay line adjustable in steps of 5 μs up to 35 μs, the intention being to adjust for minimum crosstalk between the A and B signals; for this purpose, however, the steps were described as being a little coarse. A pre-emphasis time constant of 50 μs was used, as appropriate to European broadcasting.

(ii) *Multivibrator Stereophonic Adapter*

The first of the two adapters that were operated from the Bogen f.m. tuner employed a sub-carrier demodulator of the triggered multivibrator type. This circuit has the advantage that on monophonic broadcasts, when no sub-carrier is radiated, the circuit is not triggered; the audio output then automatically achieves a normal (monophonic) performance in regard to signal-to-noise ratio, without being degraded by a large noise output from the sub-carrier channel.

(iii) *Slope-Demodulator Stereophonic Adapter*

The second adapter comprised a limiter, a simple circuit with a sloping characteristic over the sub-carrier frequency range, and a diode detector.

(iv) *Complete Low-Cost Receiver*

A simple f.m. receiver had been modified by the addition of a demodulator of the same kind as (iii) above and two audio channels to supply a pair of small loudspeakers. The additional valves compared with a monophonic f.m. receiver amounted to one double triode, one low-power pentode and one output pentode.

In addition to the stereophonic receivers, a small standard R.C.A. a.m./f.m. receiver was available for testing compatibility.

4.3. Appraisal of Demonstrations

The f.m. tuner and the adapter described under (iii) above, working into the amplifier and wide-range loudspeakers, were regarded as the standard high-grade receiving system for the complete transmitter-receiver chain. The crosstalk attenuation between the A and B channels had been measured, and was at least 30 dB over the 300 to 1000 c/s range, dropping smoothly to 15 dB at 15 kc/s and, at the lower frequency end, up to 20 dB at 30 c/s. This was checked roughly in the experimental set-up by feeding programme to the transmitter on one channel only and listening on the opposite channel on the receiver; the level and spectrum of the residual sound gave no reason to doubt the measured performance figures.

A comparison between reproduction directly from the record and through the system did not reveal any obvious difference; there appeared to be a slightly greater response at the upper frequencies when listening through the system. When we queried the latter point it was admitted that the circuits before the f.m. modulator were not exactly right and would tend to enhance the upper-frequency response slightly. It is fair to add that this appeared to have arisen from a genuine error which would be

corrected as soon as possible, and that the effect was too small to prejudice the demonstrations.

We heard all three arrangements for stereophonic reception and, with a good r.f. signal level, they appeared to work well. The tuning position was not critical for any of them. The multivibrator adapter made a rasping noise over two small ranges of tuning on either side of the correct tuning position, but at these points the audio level had decreased appreciably. The noise evidently occurred when detuning had reduced the sub-carrier level to the triggering threshold value for the multivibrator.

When the equipment was built, measurements had been made of the signal-to-noise ratio by direct connection to a signal generator, with receiver noise as the limiting factor; on this test the multivibrator adapter had proved slightly better than the other receivers, and had shown a degradation relative to monophonic reception close to the theoretical figure.

We raised the question of an experimental check of reduced effective sensitivity on stereophonic reception due to background noise from ignition interference and other electrical disturbance. Although it had not been tried before, our hosts kindly offered to reduce the r.f. level at the transmitting end to investigate reception at low field strength. Under this condition there was a faint continuous noise, with fairly frequent impulsive interference which appeared to originate partly from car ignition systems in the road nearby and partly from miscellaneous forms of electrical interference. The only quantitative comparison which could be conveniently made was that between reception of a stereophonic transmission, first, monophonically by "killing" the sub-carrier circuit of the receiver, and, second, stereophonically. The r.f. level was adjusted between the two conditions to give approximately equal signal-to-noise ratio and the change of level was 14 dB; this figure was obtained with the slope-demodulator adapter, but would apply approximately to the multivibrator adapter as well, since this was found to have about the same signal-to-noise performance on stereophonic reception under weak-field conditions. Since the monophonic reception of a stereophonic transmission would already be at least 6 dB worse in signal-to-noise ratio than that obtained from a standard monophonic transmission (due to reduced deviation of the compatible signal) this test illustrated that some 20 dB increase in field strength would be needed with receivers of the type employed to restore the performance in the presence of impulsive interference to that enjoyed in monophonic broadcasting.

We also suggested the removal and restoration of the sub-carrier at the transmitter end while listening monophonically. This revealed a slight rise in background noise level in the presence of the sub-carrier; as we pointed out, this can cause degradation of signal-to-noise ratio to the monophonic listener, additional to that arising from reduced deviation.

5. STEREOPHONIC SYSTEMS FOR M.F. BROADCAST BAND

5.1. General

A considerable amount of work has been done by the R.C.A. Research Laboratories in the U.S.A. on various stereophonic systems suitable for a.m. transmitters

operating in the m.f. broadcast band, and a comprehensive report on this has recently been published.[1] Both the theoretical analysis and the experimental work, including field trials, have suggested that the optimum system is one that radiates the M = A+B signal as the envelope of the carrier and the S = A−B signal as frequency modulation of the carrier. The recommended peak deviation for the f.m. is ± 1·25 kc/s for low modulation frequencies, pre-emphasis with a 100 μs time-constant being applied to the S signal. Perhaps the most important conclusion of the work is that the so-called "additive" systems, i.e. systems which may be regarded as simply adding to a normal a.m. transmission sidebands resulting from amplitude modulation of a signal in quadrature with the main carrier, are at a disadvantage in respect of non-linear distortion and intermodulation. The R.C.A. proposal is classed as a "multiplicative" system in the sense that frequency (or phase) modulation and amplitude modulation of the carrier are performed sequentially, so that the quadrature sidebands are modulated by the envelope signal. Although refinements to the additive system which go a long way towards overcoming the distortion difficulty were considered in some detail in the report referred to, the straightforward a.m./f.m. system still appeared superior both in performance and in simplicity of receiver design. (The system proposed by Philco is an example of one which conveys the S signal as carrier-suppressed amplitude modulation of a quadrature-phased carrier component, and would be classed as an additive system. Although it was not mentioned by name at Zürich, nor in the report, the work done at Princeton was evidently intended to include appraisal of this system.)

5.2. Demonstration Equipment

For demonstration purposes a low power signal was generated, the f.m. parameters being slightly different from those mentioned above, namely, a pre-emphasis time constant of 150 μs with a peak deviation of ± 1 kc/s at a modulation frequency of 1 kc/s. Delay-time correction (25 μs delay) was applied to the M signal. The pre-emphasised S signal was applied to a reactance valve operating in conjunction with a triode oscillator circuit. The r.f. output amplifier was screen-grid modulated by the M signal.

As far as we could see, arrangements were made to feed the receiver directly at r.f. on closed circuit; since we did not hear the systems under conditions of poor signal-to-noise ratio, the method of feeding is not important.

Two stereophonic receivers were available. The first was a modified Bogen a.m. tuner representing the equivalent of a high-grade receiver. The additional circuits employed two double-diode limiters prior to the balanced two-diode discriminator giving the S signal. The A and B outputs were derived and fed to the stereophonic amplifier and loudspeaker system used in the f.m. system tests. The second receiver was a "low-cost" design, complete with a.f. output stages for connection to the two smaller loudspeakers. The additions to a standard monophonic a.m. receiver involved a pentode limiter, a double triode, a transistor and a second output pentode.

The r.f. and i.f. circuits of a stereophonic receiver must have a frequency-response characteristic which is flat-topped and of adequate width. If this requirement is not met, crosstalk will occur from the S channel into the M channel because of unwanted amplitude modulation. A slope of the characteristic over the pass-band, for example, will produce linear crosstalk and hence a lateral displacement of the

stereophonic images. Curvature of the characteristic will produce distortion due to non-linear crosstalk, and will cause the position of the images to vary appreciably with small changes in the tuning position.

Special measures are also necessary in receiver design to preserve intact the ratio of M and S signals transmitted, since any change in this ratio is equivalent to crosstalk between left- and right-hand channels. A difficulty, however, arises because the amplitude-modulated M signal is proportional to the level of the signal arriving at the envelope detector, while the frequency-modulated S signal is independent of this if a "static" type of limiter is employed. In the more elaborate of the two receivers shown, the ratio of M to S was preserved by providing a nearly flat-topped a.g.c. characteristic and hence a substantially constant M signal. In the "low-cost" design, in which the a.g.c. permitted an appreciable variation in signal level at the detector, compensation was provided by varying the limiting level. For this purpose a transistor d.c. amplifier was used to control the screen-grid voltage of the limiter valve according to the a.g.c. voltage.

5.3. Appraisal of Demonstrations

The general impression of the stereophonic reproduction through the system with the better of the two receiving arrangements was one of very acceptable quality; the main limitation was in audio frequency response which has an upper limit of about 7 kc/s, which is nevertheless quite high by standards normally accepted in medium frequency reception. We briefly heard the low-cost receiver in operation and this, too, worked quite well within the limitations imposed by the smaller loudspeakers and the restricted a.f. range (about 5 kc/s maximum). Tuning was reasonably easy on both receivers.

A demonstration of the compatibility of the system was given using the standard a.m./f.m. receiver operating on the medium frequency range. With the M signal temporarily removed, the S signal was heard at a low level, slightly distorted. The M signal was then transmitted continuously while the S signal was intermittently applied and removed but it was impossible to detect with certainty any changes in the quality of the compatible signal.

In considering the potential application of a system of the type demonstrated it should be remembered that in the U.S.A. it has been possible to maintain good planning of the m.f. band, using 10 kc/s channels. This allows receivers with an audio frequency bandwidth of some 5 to 7 kc/s to operate with reasonable freedom from interference. The situation in Europe is much less favourable, and this largely accounts for the severely restricted bandwidth in present-day a.m. receivers. Should a European stereophonic service be started without a radical change in planning, an i.f. bandwidth considerably less than that of the receivers demonstrated would continue to be necessary over a large proportion of the service area. Undesirable effects due to the i.f. characteristic might then be more marked, both in monophonic and stereophonic reception, than those in the equipment demonstrated.

6. TRANSISTOR A.F. AMPLIFIERS

The two 15 watt transistor amplifiers used to feed the high-grade loudspeakers were housed in a relatively compact unit which produced very little heat.

Each amplifier consisted of five stages, the push-pull class-B output stage being of the type employing a driver transformer but no output transformer. Two separate 15 volt power supply circuits, operating from the mains, were used for the upper and lower halves of the push-pull output circuits; one of these supplies was used for the four remaining stages of each amplifier. This arrangement, compared with the use of a single supply, makes it easier to balance the halves of the push-pull circuits.

The total harmonic distortion in each amplifier was given as 5% at 4 watts and 10% at 15 watts. The relatively high distortion figures are associated with the limited degree of negative feedback employed — approximately 8 dB; to increase the amount of feedback it would probably be necessary to employ transistors having a higher cut-off frequency. In this connection, advance information was given on a new type of germanium p-n-p transistor, TA 1817, of comparable power rating designed for a.f. output stages and having a common-base current-gain cut-off frequency of 15 Mc/s. The TA 1817 is in pilot production and is expected to be brought out commercially early in 1961.

7. GENERAL WORK OF THE ZÜRICH LABORATORIES

7.1. Television Tuner Design

Considerable interest was taken by the Industry Service Laboratory in television tuner design and in meeting the requirements in Germany for keeping down the level of oscillator radiation;* these requirements are more severe than those in the United States. A field site was available in Zürich for oscillator radiation tests by the standard method of the International Electrotechnical Commission (I.E.C.) in which a receiver, with a dipole aerial connected to it, is examined for radiation field strength by a second dipole at a range of 3 metres. Hitherto, much of the radiation from u.h.f. tuners has been direct from the sub-chassis rather than via the aerial terminal, and improvements in methods of screening and decoupling are being made. For this application Siemens have introduced a "feed-through" component made of silvered ceramic with a ferrite tube, which provides a series lossy inductance as well as capacitance to earth on each side of the plate through which it is passed, so that a high attenuation at u.h.f. may be obtained in supply feeds. One of the main reasons why German u.h.f. tuners employ a separate r.f. stage, whereas American tuners have a crystal mixer as the first stage, is that reduction of oscillator voltage at the aerial input to the required limits is made somewhat easier.

7.2. Television Systems Laboratory

One of the laboratories was well equipped for testing television transmitting equipment and receivers. Black-and-white television picture waveforms could be generated according to the 405-, 525-, 625- or 819-line standards. In addition, N.T.S.C.-type colour pictures could be originated according to the U.S.A. standard of 525 lines, with a sub-carrier frequency near 3·58 Mc/s, and the European standard of 625 lines using a sub-carrier frequency near 4·43 Mc/s. For the operation of 525-line equipment, a 60 c/s power source was available. We saw a 625-line colour slide reproduced on an R.C.A. receiver; we were told that equal bandwidths of

*The oscillator radiation limits are 50 μV/m at 30 m range for 87·5–100 Mc/s, 150 μV/m at 30 m range for 174–223 Mc/s and 450 μV/m at 10 m range for 470–790 Mc/s.

750 kc/s were being used for the I and Q chrominance signals. The colour edge effects were rather more noticeable than on 405-line pictures seen on B.B.C. equipment, and the pictures had a certain lack of realism regarding the fidelity of flesh-tone reproduction. These are judgments of pictures which were not set up with any special care; apart from these criticisms the general standard of reproduction and definition was quite good.

An item of interest was a Japanese 17 in. (43 cm) colour tube which we saw in operation showing a 625-line picture. Apparently the incentive for the production of such a tube is the fact that, according to the present legislation, television receivers in Japan with a tube size larger than 17 in. (43 cm) are subject to a much higher rate of tax. Presumably this is expected to apply equally to colour receivers and black-and-white receivers. The tube was of the shadow mask type in which the R.C.A. standard mask had been copied without change in the fineness of the dot pattern, with the result that the dot structure appears relatively coarse on the smaller tube face. In fact, with the 625-line picture some faint moiré patterning was visible; this particular weakness may not, however, exist for the 525-line standard, which is used in Japan. The colour rendering, definition and general reproduction of the Japanese tube appeared satisfactory. We understood that the relative sensitivities of the red, blue and green phosphors were somewhat different from those in the standard R.C.A. tube and they had not been able to compensate fully for this in the picture we saw.

7.3. Transistorised Receivers

A nine-transistor f.m. receiver had been made according to a design issued in the application literature for R.C.A. transistors in the U.S.A. It followed the same lines as most European commercial transistor f.m. receivers in employing a grounded-base r.f. stage, grounded-base oscillating mixer, three common-emitter i.f. stages, and a ratio detector followed by a three-stage a.f. amplifier with push-pull output. Automatic gain control was applied to the first stage only. We were not able to hear the receiver working properly as no local f.m. stations were operating at the time of day we visited the laboratory.

We saw a Japanese transistorised television receiver which was very small in size with a directly viewed miniature tube of about 8 in. (20 cm) diagonal. It was not possible for us to see it in operation, but the design and performance were highly praised.

7.4. Research on Materials

We paid a very brief visit to the laboratory which undertakes more fundamental research in co-operation with the Princeton Laboratories in New Jersey. This has its own facilities in the way of laboratories and library, quite separate from the radio equipment side already described. The main work was on the optical and electrical properties of cadmium sulphide and other semiconductor materials. Preparation and purification of materials was carried out on the premises in a well-equipped chemical laboratory.

8. REFERENCE

1. "A Compatible Stereophonic System for the A.M. Broadcast Band", Avins, J., et al., R.C.A. Review, Vol. 21, No. 3, p. 299, September 1960.

APPENDIX

The following is the outline agenda enclosed with the invitation.

STEREOPHONIC SYSTEMS CONFERENCE
1960/61

R.C.A. Industry Service Laboratory
Zürich, Switzerland

I Introduction to Zürich Laboratories Staff and a General Inspection of Installed Facilities

II Discussion of Stereo Broadcasting Systems under Consideration in the U.S.A.

(a) Desired Overall System Performance

(b) F.M. Systems (U.K.W.)

(c) A.M. Systems (Medium Wave)

III An F.M. Stereo Broadcasting System — technical details — equipment demonstration — system performance

(a) Transmitter Equipment — sub-carrier generation — matrixing networks — delay compensation

(b) Receivers — i.f. and detector requirements — sub-carrier demodulation — audio filters — matrixing networks

1. High quality receiver design
2. Low cost receiver design

IV An A.M. Stereo Broadcasting System — technical details — equipment demonstration — system performance

(a) Transmitter Equipment — modulation method — matrixing network — delay compensation

(b) Receivers — i.f. and detector problems — gain tracking — f.m. demodulation — matrixing networks

1. High quality receiver design
2. Low cost receiver design

V Stereo Audio Devices — power drift transistor applications

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